ient waste management system overall (with less organic content to land apply).

The decomposition process will be anaerobic or aerobic. Anaerobic bacteria in animal waste (i.e., bacteria that live in animal intestines) cannot work in the presence of oxygen. Aerobic bacteria, on the other hand, must have oxygen; therefore, anaerobic lagoons are deep and airless; aerobic lagoons are spread over a large surface area, take in oxygen from the air, and support algae. Both aerobic and anaerobic lagoons provide storage and disposal flexibility.

Other factors, however, must also be considered. Anaerobic lagoons are a source of odors and nitrogen losses and may require frequent sludge removal if they are undersized. Groundwater protection may be difficult to secure in either system. If mechanical aeration is used for an aerobic system, energy costs must be included in the accounting. Proper management is essential for lagoon maintenance and operation.

Aerobic Lagoons

The design, shape, size, capacity, location, and construction of the lagoon depends on its type. Aerobic lagoons require so much surface area (to maintain sufficient dissolved oxygen) that they are an impractical solution to most waste management problems. They may require 25 times more surface area and 10 times more volume than an anaerobic lagoon. Nevertheless, some growers may consider using an aerated lagoon — despite its expense — if they are operating in an area highly sensitive to odor.

Some of the sizing difficulty can be solved by using mechanical aeration — by pumping air into the lagoon — but the energy costs for continuous aeration can be high. Aerobic lagoons will have better odor control, and the bacterial digestion they provide will be more complete than the digestion in anaerobic lagoons.

Lagoon design and loading specifications should be carefully followed and monitored to increase the effectiveness of the treatment. No more than 44 pounds of biological oxygen demand (BOD) should be added to the lagoon per day per acre. The lagoon should have sufficient depth so that light will penetrate the 3 or 4 feet of water. Effluents from the lagoon should be land applied to avoid long-term ponding and to make economical use of the nutrients that remain in them.

Anaerobic Lagoons

Anaerobic treatment lagoons are earthen basins or ponds containing diluted manure that will be broken down or decomposed without free oxygen. In the process, the organic components or BOD in the manure will be liquified or degraded naturally.

Anaerobic lagoons must be properly designed, sized, and managed to be an acceptable animal waste treatment facility.

Liquid volume rather than area determines the size of anaerobic lagoons. The lagoon should accommodate the design treatment liquid capacity and the amount of wastewater to be treated; it should also have additional storage room for sludge buildup, temporary storage room for rain and wastewater inputs, extra surface storage for a 25-year, 24-hour storm event, and at least an additional foot of freeboard to prevent overflows.

The design criteria for anaerobic lagoons are based on the amount of volatile solids to be loaded each day. The range is from 2.8 to 7.0 pounds of volatile solids per day per 1,000 cubic feet of lagoon liquid. The amount of rain that would collect in a 24-hour storm so intense that its probability of happening is once in 25 years requires at least 5 to 9 inches of surface storage, although the actual volume of surface storage required is site specific.

To protect the groundwater supply, lagoons should not be situated on permeable soils that will not seal, on shallow soils, or over fractured rock. The bottom of the lagoon should not be below the water table. Nor should mortalities be disposed of in lagoons. In fact, screening the wastes before they enter the lagoon helps ensure complete digestion and the quality of the wastewaters for land applications. If the site's topography indicates a potential for groundwater contamination, then any earthen basin should be lined with clay, concrete, or a synthetic liner.

New lagoons should be filled one-half full with wastewater before waste loading begins. Planning start up in warm weather and seeding the bottom with sludge from another lagoon helps to establish the bacterial population. Because bacterial activities increase in high temperatures, lagoons, in general, work best in warm climates. Manure should be added to anaerobic lagoons daily, and irrigation (drawdown) should begin when the liquid reaches normal wastewater maximum capacity. The liquid should not be pumped below the design level treatment, however, because the proper volume must be available for optimum bacterial digestion.

Drawdown (that is, the lagoon liquid) can be used for land applications guided by regular nutrient management planning and sampling of the lagoon liquids and soils to ensure safe and effective applications. When sludge accumulation diminishes the lagoon's treatment capacity, it, too, can be land applied under strictly monitored conditions.

Secondary lagoons are often needed for storage from the primary lagoon. Using a secondary lagoon for irrigation also bypasses some of the solids picked up in the primary lagoon. The size of secondary lagoons is not critical.

Information and technical assistance and some cost-share programs are available for producers who determine that a lagoon system should be part of their resource management system. The USDA Natural Resources Conservation Service (NRCS) and the Cooperative State Research, Extension, and Education Service offices can provide additional assistance.

Land Applications

Land application of liquid waste can be achieved with a manure slurry or irrigation system. If the application falls directly on the crop, care must be taken to prevent ammonium toxicity and burning. Because raw manure contains high amounts of uric acid, it should be thoroughly mixed before application. Layer lagoon sludge is more dense than a pullet lagoon sludge because of its high grit or limestone content and should be diluted before application.

Timing is a major factor in successful land applications. There should be no land application prior to, during, or immediately following a rainfall event. The manure must also be uniformly applied — whether you are using a manure spreader or an irrigation system. The operator should be particularly careful (especially during a drought) not to coat the plants with lagoon liquid. Instead, make several small applications of lagoon liquid, rather than one large one.

Liquid waste is primarily disposed of through land applications. Proper spreading on the land is an environmentally acceptable method of managing waste. However, with increasing environmental concerns and the need to match closely the fertilizer needs of crops, farmers can no longer afford to simply "spread manure."

The USDA NRCS, Cooperative State Research, Extension and Education Service, and other agencies offer poultry waste and nutrient management planning assistance. These offices have worksheets to help growers plan liquid waste management, which includes the following tasks:

- ▾ determining the amount and volume of waste generated;
- ▾ calculating land application requirements;
- ▾ sampling and analyzing the nutrient composition in poultry litter, manure, or slurry; and
- ▾ matching the nutrients available in these products with crop nutrient requirements for land applications.

Detailed information on how to prepare nutrient assessments, conduct soil testing, and calculate application rates, timing, and methods of application are also available from these agencies.

The use of nutrient management planning will help growers make economical and practical use of the organic resources generated on their farms.

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Composting Waste Products

Poultry litter or layer manure is most often land applied to pastures and crops for its value as an organic fertilizer. We know from long experience how beneficial this practice can be when soil and manure nutrient testing are integrated with crop nutrient needs to determine the amount and timing of the application. This integration makes it possible to approach land application as a wise use of resources rather than as a disposal method.

Proper storage and treatment of poultry by-products (litter, manure, hatchery waste, and dissolved air flotation [DAF] skimmings) before use are important to minimize compositional changes and decrease odor and handling problems. Depending on the by-product, dry storage, ensiling, or composting may be appropriate treatments. Resource management systems may include incineration and burial as methods of disposal; however, these techniques are not called treatments because they do not usually provide any reusable products.

Composting is an environmentally sound and productive way to treat poultry by-products and mortalities (see also PMM/4 and PMM/5). The product of composting is easier to handle, has a smaller volume, and is a more stable product than the raw materials. The nutrient content of the compost will be nearly the same as the starting materials if the composting is performed properly.

While compost can be land applied to decrease the need for nutrients from commercial fertilizers, composted by-products may also be marketed for higher value uses on turf, for horticultural plant production, and in home gardening landscaping. It can be added as an amendment to soils for transplanting flowers, trees, and shrubs, or to establish new lawns. Compared to commercial fertilizers, poultry by-product compost will have a lower nutrient analysis (e.g., 2-2-2) for nitrogen, phosphorus, and potassium. However, there are other benefits to the soil and plant growth associated with the organic matter and micronutrients in compost.

Understanding the Process and Benefits of Composting

Composting is a natural, aerobic, microbiological process in which carbon dioxide, water, and heat are released from organic wastes to produce a stable material. Leaves and other organic debris are subject to this process all the time — that is, the activity of microorganisms transforms these materials into a soil-like, humus-rich product.

This natural process can also be used as a resource management technique to transform large quantities of litter, manure, and other poultry by-products into compost. The conditions under which natural composting occurs can be stimulated and controlled so that the materials compost faster and the nutrient value of the compost is maximized.

The composting process is relatively simple:

1. By-products, for example, litter, manure, eggshells, hatchery waste, and DAF skimmings, are placed in bins, piles, or elongated piles called windrows. A bulking agent or carbon amendment (e.g., sawdust, wood chips, yard waste, or paper that is rich in carbon but low in other nutrients) is usually necessary to provide the proper ratio of carbon to nitrogen in the mix and to improve aeration.

2. Air is needed to support and enhance microbial activity. Because the composting microorganisms are aerobic, that is, oxygen using, the windrows and compost piles must be aerated to ensure the

efficiency of the process. Sufficient aeration also minimizes the formation of objectionable odors that form under anaerobic (oxygen depleted) conditions. Adequate aeration can be provided by forced air systems, such as blowers or fans; or by turning the compost with a front-end loader or a commercially available compost turner as required.

3. Mechanical agitation or turning of the materials supplies aeration, helps mix the materials, and distributes any added water.

4. Temperatures in the compost must be maintained at levels above approximately 130°F to kill any pathogens (disease-causing organisms) and promote efficient composting. Temperatures above 150 to 160°F should be avoided because they reduce the microorganisms that are beneficial to the composting process.

5. Adequate moisture, between 50 and 60 percent, is necessary for optimal microbial activity.

Handling Compost

Compost produced from poultry by-products can be used in many different ways: it can be used directly as a soil amendment for agricultural or horticultural uses; pelletized or granulated for ease of transportation and application; or enhanced with conventional fertilizers to improve its nutrient value.

Even though composting is a relatively new manure management technology, the off-farm market is clearly growing. Consumer awareness of the safety and convenience of the product is beginning to penetrate the market. Current limiting factors are growers' unfamiliarity with marketing strategies and competition from less costly products.

Possible Drawbacks

Composting, like any management technique, cannot be undertaken lightly, whatever its benefits. It requires a commitment of time and money for equipment, land, storage facilities, labor, and management. Composting is an inexact process that depends heavily on the quality and characteristics of the materials being composted and the attention given to the composting process.

Although the finished product should have no odor or pest problems, such problems may occur during the composting process. Weather may also affect the process adversely. Compost releases nutrients slowly — as little as 15 percent of the nitrogen in compost may be available during the first year of application. In addition, costs associated with production-scale composting can be significant, and federal and state regulations for stormwater runoff from the composting site must be followed.

Despite these potential drawbacks, composting on the farm is a practical resource management technique. Good management will consider every opportunity to eliminate or reduce the concerns associated with composting while maximizing its benefits. Once it is realized that composting can be more than a "dump it out back and forget it" procedure, the technique can be used and adjusted to meet by-product management needs.

Composting Methods

There are four general methods of composting: passive composting, windrows, aerated piles, and in-vessel composting.

- **Passive composting** is the simplest, lowest cost method. It requires little or no management because the materials to be composted are simply stacked into piles and left to decompose naturally over a long time.

  Passive composting is not suitable for the large quantities of litter or manure produced on poultry farms. It occurs at comparatively low temperatures and decomposition occurs at a slow rate. Anaerobic conditions resulting from insufficient aeration can result in objectionable odors.

- **Windrow composting** occurs in long narrow piles that can vary in height and width depending on the materials and equipment available for turning.

  For most efficient composting, windrows are turned as required depending on temperature and oxygen measurements.

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Windrow composting (Fig. 1) is usually well suited to poultry farms. In this method, the windrows are formed from the material to be composted, water, and any bulking agent or carbon amendment. The piles can range from 3 feet high for dense materials to as high as 12 feet for lighter, more porous materials like leaves. If the piles are too large, anaerobic conditions can occur in the middle; if they are too small, insufficient heat will be maintained for pathogen reduction and optimum microbial activity.

The windrows are turned periodically to add oxygen, mix the materials, rebuild porosity (as the mixture settles), release excess heat, and expose all materials equally to the high interior heat that kills pathogens. Turning can be labor and equipment intensive depending on the method used. In the beginning, it may be necessary to turn daily or even several times a day to maintain sufficient oxygen levels; however, turning frequency declines with the windrow's age.

In addition to needing space for the windrows, the producer will also need turning equipment, a source of water, a dial thermometer, and perhaps an oxygen meter. The turning equipment (Fig. 2) can be front-end loaders, manure spreaders with flails and augers to provide good mixing, or specialty machines. Often older, unused farm equipment, for example, an old potato plow and a farm tractor, can be used for turning compost.

Temperatures within the windrow are most commonly used to determine when turning is necessary. Low temperatures and odors are signs that more oxygen is needed, while cool or hot spots at intervals along the windrow indicate that the material needs to be mixed. During fly season, all windrows should be turned at least weekly. In the winter, windrows can be combined to conserve heat as they diminish in height. Composting time can vary from weeks to months depending on the material being composted, the attention given to composting conditions, and the quantity of material composted.

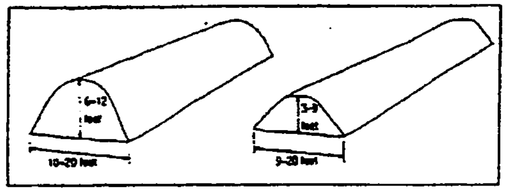

Figure 1.—Typical windrow shapes and dimensions.

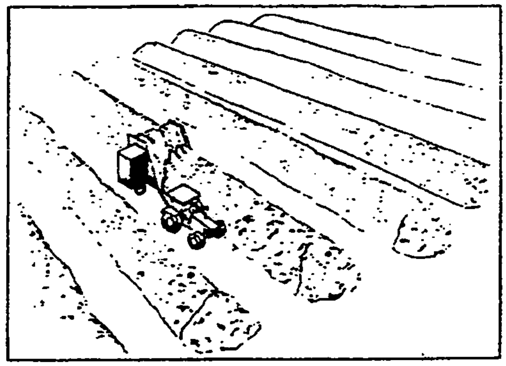

Figure 2.—Windrow composting with an elevating face windrow turner.

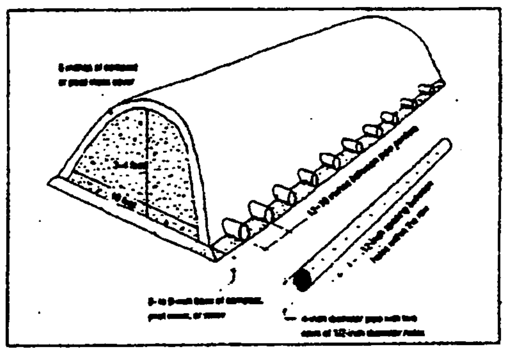

Figure 3.—Passively aerated windrow method for composting manure.

▼ **Aerated static composting** eliminates the labor of turning the compost by using perforated pipes to introduce air into piles or windrows.

Air can be supplied passively, or with blowers to force air into or through the composting material.

Passively aerated windrows (Fig. 3) are a modification of windrow composting that eliminates turning. In a commonly used system, the windrow is placed on a base of wood chips, straw, or peat, and perforated aeration pipes are added on top of this base. The material to be composted must be very well mixed, since it is not turned, and the windrow should not be higher than 3 to 4 feet. This method has the advantage of minimizing odors and helping to conserve nitrogen.

Aerated static piles or windrows add blowers to the aeration pipes. This method allows larger piles or windrows and permits more efficient composting than passively aerated static piles. Air can either be drawn into or forced through the composting material. The blowers may be controlled to turn on at set intervals or in response to temperatures in the pile or windrow.

▼ **In-vessel composting** is similar to aerated methods but the materials to be composted are contained in bins or reactors that allow for control of aeration, temperature, and mixing, in some systems.

In-vessel composting is actually a combination of methods that involve both aeration and turning. The advantages of in-vessel composting include the elimination of weather problems and the containment of odors. In addition, mixing can be optimized, aeration enhanced, and temperature control improved.

The simplest form of in-vessel composting is bin composting, which is readily adaptable to poultry farms. Bins may be plain structures with wood slatted floors and a roof, conventional grain bins, or bulk storage buildings. Other types of in-vessel composters use silos in which the air goes in at the bottom and the exhaust is captured for odor control at the top; agitated bed systems; and rotating drums. Costs for equipment, operation, and maintenance for a large quantity of materials are high for in-vessel composting.

Factors to consider in choosing a composting method are speed, labor, and costs. Windrows are common on farms; they can use existing equipment, no electricity is required (so they can be remotely located), and they produce a more uniform product. They are, however, also labor intensive and at the mercy of the weather. Adding a paved or compacted clay surface and a simple open-sided building can minimize weather problems and the impact of composting on water quality.

For more information, technical assistance, and possible cost-share programs that may be available to help you begin a composting operation, contact your local conservation district office, the USDA Natural Resources Conservation Service, or the Cooperative State Research, Extension, and Education Service.

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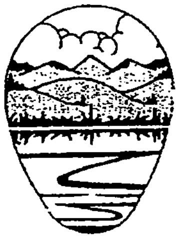

Putting Nutrient Management to Work

Land application, especially field spreading, is in most cases the best use of poultry wastes. It recovers nutrients that would otherwise be lost, improves yield, and reduces the possibility of releasing this material to water and the environment.

Where land is available, manure applications can be substituted for commercial fertilizers, reducing the farmers' costs and helping them comply with environmental laws. At the same time, land applications tend to use the largest amount of waste closest to the point of production.

To ensure that nutrients in waste are not overapplied to the land, the waste must be analyzed for the amount and type of nutrients it contains and the timing of applications must be adjusted to ensure that growing plants can use the nutrients. To accomplish this outcome, the litter should be uniformly applied at the recommended rate. The management practice that offers this assurance is nutrient management planning.

Nutrient management planning as a preliminary to land application has become a standard practice for recovering and using the nutrients in solid and liquid animal waste. It is, like composting, a centuries-old practice, which modern technology has substantially improved. The improvement — in a word — the ability to plan exactly how much manure should be applied — was highly recommended in the early 1990s. In 1995, the poultry industry in the Commonwealth of Virginia announced the decision of its four major integrators to require all new producers to have nutrient management plans. Nutrient planning has since become a requirement in many states.

What Is a Nutrient Management Plan?

Nutrient management planning matches the nutrient needs of the plants and soil with the nutrient contents in the manure to achieve a proper nutrient balance. An effective nutrient management plan consists of the following core components:

- farm and field maps,
- realistic yield expectations for the crops to be grown,
- a summary of the nutrient resources available (the results of soil tests and nutrient analyses of manure, sludge, or compost),
- an evaluation of field limitations based on environmental hazards or concerns (e.g., sinkholes, land near surface water, highly erodible soils, steep slopes),
- application plans based on the limiting nutrient,
- plans that include proper timing and application methods (avoid application to frozen soil and during periods of leaching or runoff), and
- calibration of nutrient application equipment.

Experience will continue to refine this practice. For example, nutrient management is very often based on nitrogen as the limiting nutrient. Nitrogen is a challenging nutrient to manage; it is highly mobile, easily dissolving in runoff and leaching through soil. Phosphorus, on the other hand, is less mobile so it is less likely to move off-site. Buffer zones and filter strips are also planted at the edge of fields and around water resources — to protect them from both nitrogen and phosphorus.

Now, however, soil tests and soil performance are showing relatively high phosphorus levels even in areas that have not been traditionally high in phosphorus. In some cases, these levels are so high that phosphorus must now be used as the limiting nutrient; in other cases, the levels are so excessive that no phosphorus should be applied, perhaps for a very long time. And while buffer strips are helpful, they are not sufficient to reduce phosphorus to acceptable levels.

These conditions notwithstanding, phosphorus is an essential element in bird nutrition. Are we then facing a dilemma? If we go carefully into these new areas, probably not. The solution may be found in enzyme treatments or food additives. Many growers have shown that putting the enzyme phytase in the diet can help maintain bird health and reduce the amount of phosphorus in litter. Phosphorus reductions can also be achieved by treating litter and field soils with alum. As alum treatments also reduce ammonia volatilization, growers are once again provided with a key management notion: good waste management, bird nutrition, and maintaining good management practices year-round are interrelated.

The USDA Natural Resources Conservation Service and Cooperative State Research, Extension, and Education Service offices have prepared tables of the mean average amounts of key nutrients found in different kinds of manure (Table 1). These tables may be used to estimate the nutrient content of your waste source or stockpile. However, as this resource is produced and used under many different circumstances, it is always best to have samples of your supply tested periodically by a certified state or private lab.

Preparing Samples

Always prepare your samples from six to 12 representative areas in the poultry house or from at least six different locations in the stockpile. (Samples collected from the stockpile should be taken from a depth of about 18 inches; careful handling will ensure that no soil is intermixed in the sample.) Samples should be taken as close as possible to the time of application; however, allow sufficient time to receive test results.

To collect the sample, obtain a quart of waste from six to 12 locations in the house or stock pile and place them in a large, clean bucket. Mix the contents thoroughly; then place about a quart of the mixed sample into a clean plastic bag or bottle. Seal it tightly, but allow room for the sample to expand. Keep the sample cool; if it is not mailed to the laboratory on the same day as it was withdrawn from the source, then the entire sample should be refrigerated. The accuracy of the lab test depends on the quality of the samples collected. Contact the lab that will be analyzing your sample for information on collection, handling, and shipping.

For Best Results

Both dry and wet samples should be routinely tested on an "as is" basis for total nitrogen, ammonia-nitrogen, phosphorus, and potassium. The key to successful land applications is to apply the right amount of nutrients at the right time, using the right method so that the waste's nutrient content is closely correlated with the nutrient needs of the plants and soil. Be aware that some nutrients will accumulate in the soil and reach high levels; apply the product immediately before planting, during a high growth season, and not in bad weather (when the nutrients may be washed away). Incorporate waste into the soil, if possible. For best results, use biennial soil tests in connection with your manure sample and basic calculations.

Land Application Rates and Methods

Whether the poultry manure or litter waste is taken to nearby farms or spread on your own land, the amount applied, the timing of the applications, and the methods used will affect the outcome. Understanding how the soil and manure or litter interact and calibrating the spreader will help growers apply the right amount at the right time in just the right way.

Manure spread on the surface and not worked into the soil will lose most of its volatile nitrogen compounds, which will be released as ammonia gas to the atmosphere. This release may or may not represent a pollution potential, but such lost nutrients are not available for plant growth.

Poultry waste spread on frozen or snow-covered soil has a high potential for runoff to

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Table 1.—Average Nutrient Composition of Poultry Litter, measured in lbs/ton on an as is basis.

	N	NH_4+-N	P_2O_5	K_2O	Ca	Mg	S	Na	Fe	Mn	B	Mo	Zn	Cu
Broilers Stockpiled litter	36	8	80	34	54	8.0	12.0	6.2	1.5	0.59	0.041	.00069	0.55	0.27
Layers Undercage	28	14	31	20	43	6.1	7.1	4.5	0.52	0.27	0.050	.00390	0.32	0.036
Highrise stored	38	18	56	30	86	6.8	8.8	5.0	1.8	0.52	0.046	.00038	0.37	0.043
Turkey Litter Stockpiled	36	8	72	33	42	6.8	9.5	6.4	1.5	0.62	0.047	.00095	0.56	0.34
Duck Litter Stockpiled	24	5	42	22	27	4.4	5.6	8.8	1.2	0.47	0.030	.00030	0.47	0.50
Liquid Layer Liquid slurry	62	42	59	37	35	6.8	8.2	5.3	2.9	0.42	0.040	.018	0.43	0.080
Lagoon sludge	26	8	92	13	71	7.2	12.0	4.2	2.2	2.3	0.082	.014	0.80	0.14
Lagoon liquid	179	154	46	25	266	7.4	52.0	51.0	2.0	0.24	0.37	.020	0.70	0.19

Source: Adapted from Soil Facts: Poultry Manure as a Fertilizer Source (Zublena, Barker, and Carter, 1993).

Key: N = nitrogen
NH_4+–N = ammonium
P_2O_5 = phosphorus
K_2O = potassium
Ca = calcium
Mg = magnesium
S = sulfur
Na = sodium
Fe = iron
Mn = manganese
B = boron
Mo = molybdenum
Zn = zinc
Cu = copper

surface water. It should not be surface applied to soils near wells, springs, or sinkholes or on slopes adjacent to streams, rivers, or lakes. In fact, some states prohibit this activity. Conservation practices can reduce runoff, nutrient loss, and pollution.

Water pollution potential can be decreased, and the amount of waste nutrients available to plants can be increased, by working poultry waste into the soil either by tillage or by subsurface injection. Subsurface injection of waste only minimally disturbs the soil surface and would be appropriate for reduced till and no-till cropping systems.

Manure or litter must have time to break down before the nutrients in it become available to the crop. Fall applications allow this breakdown to occur, but some of the nitrogen in the manure may be lost through leaching and runoff. Spring applications prevent this nitrogen loss but do not allow enough time for the breakdown of the manure. Incorporation of poultry waste beneath the soil surface in the fall is a way to conserve the nutrients and protect water quality.

Spring and summer applications are recommended based on plant uptake, though it is always important to check for good weather before applications are planned. If litter is applied in bad weather, nutrients may be lost in stormwater runoff. Nutrient-enriched runoff from agriculture could be a leading cause of nonpoint source pollution.

How the poultry waste is applied also affects how quickly the nutrients are incorporated. Generally, incorporation within 12 hours is ideal. The waste can be broadcast over the whole field, followed by incorporation tillage. This method has the advantage of good distribution; because it is visible, the grower can determine the uniformity of the broadcasting. There will, of course, be some odor on the day of the application. Farmers may also want to investigate incorporation, topdress, sidedress, and band application methods.

Spreader Calibrations

Calibration of the spreader machine is also necessary to monitor and control the amount and uniformity of the application. Calibration specifies the combination of settings and travel speed needed to apply nutrients at a desired rate. By knowing a spreader's application rate, and using a few basic calculations found in various fact sheets, a producer can correctly apply the nutrients to meet the needs of the plants. Generally, there are two types of nutrient spreaders — solid or semisolid and liquid. Broiler growers handle solid or semisolid nutrients; many egg producers have liquid waste systems.

Solid or semisolid waste is usually handled in box-type or open-tank spreaders, and the application rate is expressed in tons per acre. Nutrient concentrations in pounds per ton can be estimated, or calculated from the lab analysis. The nutrient application rate in pounds per acre must be determined, based on the tons per acre of waste application.

Liquid or slurry waste is usually handled by tank wagons or irrigation systems, and the application rate is expressed in gallons per acre. Nutrient concentrations in pounds per gallon (or pounds per 1,000 gallons) can be estimated or obtained from lab analysis and used with the application rate in gallons per acre to obtain pounds per acre nutrient applied.

The volumetric capacity of spreaders is generally provided by the manufacturer. Caution should be exercised in using manufacturer's data for spreader volume. A more accurate and preferred approach is to calibrate your own equipment.

Assistance is available from the USDA Natural Resources Conservation Service or Cooperative State Research, Extension, and Education Service offices to calibrate your spreader. Worksheets are available to determine spreader capacity and application rate. Unless the waste has been analyzed for nutrient content and unless the crop soil nutrient needs are known, spreader calibration may have little effect on the application's success.

Once the desired application rate is obtained, record the pertinent information so that you do not have to recalibrate the spreader each time it is used. Spread poultry wastes in a uniform manner. If lush, green growth and not-so-lush growth of plants are observed, adjustments will need to be made during the next application. Calibration of the nutrient spreader is an important practice that is economically and environmentally useful.

A nutrient management plan should be periodically updated to ensure its effectiveness. Often nutrient management can save a producer money by reducing the amount of fertilizer purchased. This reduction in cost is a result of accounting for nutrients already in the soil and manure. For more information, or for nutrient management planning assistance, contact your local USDA Natural Resources Conservation Service or Cooperative Extension Service office or a nutrient management consultant in your area.

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Other pages in this handbook contain more detailed information on these subjects. The Poultry Water Quality Consortium is a cooperative effort of industry and government to identify and adopt prudent uses of poultry by-products that will preserve the quality of water for everyone.

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Economics of Transporting Poultry Manure and Litter

Managing large amounts of poultry litter successfully can involve economic and environmental issues that intertwine and often appear nearly insurmountable. For example, when land suitable for spreading poultry litter as a fertilizer is not available or not under the control of the poultry grower, new markets for land applications and new ways to use the waste must be found. For some years, high quality poultry waste has been marketed both as a fertilizer and as beef cattle feed. Marketing this material involves transportation from the point of production to the point of use.

A Concentrated Industry

The locations of most poultry growers are concentrated within a 25 to 50 mile radius of a hatchery, feed mill, or live-bird processing plant. When the production radius increases over 25 miles, the cost of broiler production increases one cent per pound. This increase, resulting from a combination of labor and transportation, can cost a broiler production unit an additional $2 million annually.

The cost of protecting and preserving water quality must also be applied. Is it better to increase the area of production so that all waste products can be accommodated? Or better to transport the by-products to other areas?

For example, suppose that a broiler complex, which includes pullets and breeders, handles about one million birds a week. These birds will produce about 65,000 tons of litter annually. At the rate of 4 tons per acre, the producer will need 16,250 acres to use the litter for land applications. If more than the one company is operating in the area, even more waste will be produced and more land will be needed.

One alternative to land applications in the area of production is to generate markets or disposal areas at a point some distance from the point of production. Growers will need to find buyers for their poultry waste, and develop a transportation system or delivery network. In some instances, custom cleanout operators will broker and transport the litter for a percent of the profit.

Estimating the Break-even Point

Because of the bulkiness of the solid or semi-solid product, transportation will be the litter buyer's highest cost. An average farm truck can carry 9 to 12 tons. A 30-foot, open trailer used for transporting grains can carry 18 to 24 tons. As load size increases, the cost per ton should decrease.

Figure the cost on a round-trip basis, but if you can schedule back-hauls in the empty truck, you can push the cost even lower. Early estimates predict the cost of transporting litter to be about $1 per mile on a round-trip basis for a 20-ton load. Back-hauls are certainly feasible, with proper attention given to handling, maintenance, and truck cleaning to prevent the spread of pathogenic bacteria and viruses. At least one integrator (Tyson Foods) has approved the use of the same trucks for delivering clean bedding and back-hauling litter.

If the grower is paid a per ton price ranging from $5 to $10, and the litter has a value of $22 to $28 as a fertilizer or $40 to $80 as a feed ingredient; the buyer can afford to transport the litter 100 miles for land applications or up to 300 miles for use as a feed. These distances can be increased if sufficient litter applications are made in the buyers' watersheds to convince farmers that spreading litter on their farms really does improve soil quality and increase crop yields.

The key to this outcome depends on the poultry growers designing and operating animal waste management systems that increase the quality and uniformity of the litter. When both sides are thus engaged, the price of the litter will reflect a fair exchange between what the growers and transporters are paid and the value of the product to the buyers.

Other Practical Considerations

A method is needed for loading raw litter into trucks that have 11-foot sides. Front-end loaders or an elevator that can be loaded with a smaller tractor or skid loader will work. The storage facility must have a smooth hard pad to accommodate the loading process, and the litter must be free of foreign materials such as soil, rocks, broken glass, or other debris. It should also be covered during storage and transportation to prevent losses, protect it from stormwater runoff, and prevent any negative perception of the poultry industry by the public.

Roads and turn-around areas at both ends of the trip must be large enough to accommodate the trucks and the loading and unloading process, and storage facilities must exist at the delivery depot if land applications or other use will be delayed.

The quality of the waste must be protected, and its transport must be biologically secure. Poultry waste should be transported only from well-managed and disease-free farms. All trucks should be properly cleaned and disinfected, and any leakage from the trucks should be drained and diverted from runoff and groundwater. Before being transported off-farm, the product should be deep stacked so that the heat in the stack can kill any harmful microorganisms. The heat level must be monitored to avoid reducing its nitrogen content or creating a fire hazard. Growers may also develop composting or pelletizing treatments to reduce the litter's bulk and odor.

Developing a Transportation Network

The knowledge that litter can be safely and economically transported is not likely to increase its use immediately. In fact, regulations often discourage or prohibit spreading the litter anywhere but on the growers' own crops; and many farmers who have croplands available are convinced that other problems associated with litter, such as handling problems, high transportation costs, and environmental risk, undercut its usefulness. In addition, other waste generators are competing for the same land and can often supply their product at lower cost.

Changing conventional attitudes and helping busy, often undercapitalized farmers develop environmental and market savvy is a long-term objective that requires cooperation among all players: farmers, their research and industry partners, government decisionmakers, environmentalists, and the public.

An example of such cooperation is Winrock International Institute's three-year effort to create a market for poultry litter in Arkansas (see box). Winrock's effort was supported by the USDA Sustainable Agriculture Research and Education program, had many government and private partners, and no doubt, stands among other similarly innovative projects in other regions and countries. It is unique, however, in its determination to use the emerging market for poultry litter to "link and resolve two environmental issues": poor soil quality in some agricultural watersheds and an oversupply of poultry wastes in others.

The Winrock initiative led to progress in rural productivity, sustainability, and equity. It also involved major obstacles:

- farmers are not marketers by training or inclination, and most people living on the margin are risk adverse;
- information and training are difficult to disseminate;
- management practices must be implemented to increase the nitrogen content of litter and its overall quality;
- certification and training are needed for clean-out contractors; and
- emerging markets for litter, like other new product marketing, may need to be subsidized.

More important, perhaps, than any other consideration: the cost of transporting litter long distances and the transportation infra-

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structure generally must be carefully managed to ensure that the litter being moved is actually moving away from production areas with the most critical environmental stresses.

Ground-testing the Possibilities

Currently, a broker in central Arkansas is shipping about four 24-ton trucks of litter per day to row-crop farmers in the Arkansas delta, Mississippi, and Missouri. The cost to the buyer is $28.50 per ton for litter delivered a distance of several hundred miles.

Most of the transported litter is currently used as a soil builder and yield booster, though high quality, odor-free compost is also being marketed for use on golf courses, and in other specialty markets. These long-haul brokerage services began as enterprising local clean-out businesses. While subsidies are still needed to strengthen the market, the development and acceptance of high quality litter as cattle feed (a higher priced product) could ensure the truckers' long-term future.

At this stage, truckers depend on the research and information campaigns sponsored by federal and local agencies, agricultural foundations, and independent researchers, but the emerging market is also a catalyst for new research and farming opportunities. Indeed, the relationship between animal waste management technologies and a thriving litter transportation market is symbiotic. Both are needed to

- provide additional income to poultry growers,
- depend on incentives rather than regulations to encourage proper waste management practices,
- create a steady demand for litter in less developed watersheds, and
- create new job opportunities as well as cleaner water supplies in rural areas.

When one is convinced that litter is not a waste, but an economic asset, the logical next steps are to demonstrate its value and put it on the market.

Poultry Litter Goes to Market — Winrock's New Approach to Environmental and Rural Development

Rice farmers in western Arkansas often level their fields. The practice makes the fields easier to irrigate and drain and more accessible during bad weather. The grading, however, which is quite labor intensive, also leads to poor yields because it removes so much topsoil. The topsoil can be stockpiled during the grading and respread over the cut red clay; still, it can take some time before the fields return to high yields.

So when university researchers and some farmers began getting high yields using litter on graded soils, word of their success quickly spread to other farms. Soon cotton and soybean farmers were also using poultry litter on fields.

The loss of topsoil on leveled rice fields and other cropping practices are a potential threat to water and soil quality; so is the increasing volume of poultry litter in some regions. Using a well-planned waste management system to ensure that the litter is of high quality, then hauling it out of the threatened regions for application on croplands in other areas will solve both problems. The usefulness of the litter to crop farmers will raise growers' income even as the litter-improved soils lead to higher incomes for the farmers.

Winrock International disseminated the research findings, surveyed farmers and cleanout contractors to identify barriers to moving the litter, then linked the buyers and sellers, researchers and government resources, to begin the long process of creating a multistate market for poultry litter.

In this scenario, market forces replace regulations as a solution for environmental problems. As demand for the litter grows, so will production practices that enhance its quality and lead to new uses. The raw material can be processed for sale as potting soil, topsoil, fertilizer, plant food, and cattle feed ingredient. Moreover, as these products prove successful, other opportunities and products will be developed to increase litter's marketability and value.

The Farm Bureau has continued the project by managing the Poultry Litter Hotline. Call 1-800-467-3898 to buy or sell litter in Arkansas.

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FEEDING LITTER TO BEEF CATTLE

Cattle, so far as growth and performance can indicate, enjoy a basic diet of corn and soybean meal (for protein) and hay (for long, crude fiber). Broiler and turkey litter and caged layer waste (the latter has no litter content and is often called dried poultry waste [DPW]) can be mixed with the corn/soybean meal and fed to cattle and other ruminants (e.g., sheep and goats). This cost-effective mixture has been a common practice in the beef cattle industry for many years with no adverse effects on the animals' growth or the quality of meat and other food products processed from them for human consumption.

Indeed, as litter is a source of protein, energy, and minerals, its use as a feed ingredient helps conserve nutrients and offset other production costs. Nutrients in the litter (especially, nitrogen, phosphorus, and potassium) and various minerals are recycled to the land when excreted in the ruminants' manure. Therefore, even if the litter must be transported long distances, feeding it to ruminants can be an economical and environmentally sound waste management technique.

Although no problem arises as a result of feeding litter to cattle, the public perception of litter as a cattle feed is often based on misinformation. We readily accept and even prefer vegetables that are organically grown — mushrooms, for example, go directly from the manure bed to the grocery store — but we have a hard time accepting litter as a food ingredient. In reality, beef cattle and other ruminants have a unique digestive system — a four-chambered stomach — that is well able to process wastes and other by-products. A cow's food is broken down and processed much more completely than a plant assimilates food into its tissues.

Regulations on Feeding Litter

In 1967, the Food and Drug Administration (FDA) discouraged the use of litter as a cattle feed. But in 1980, FDA issued a statement leaving it to the states to oversee this practice. At least 22 states have current regulations. No state regulates the private use or exchange of litter for this purpose; many states, however, regulate this commodity on the commercial market.

Many states require that processed broiler litter offered for sale carry warning labels about the presence of any drugs that may be present in the litter. To minimize the potential for drug residues in the cattle, all litter feeding should be discontinued at least 15 days before the animals are marketed for slaughter. This responsibility for selling only wholesome animals falls on the producers, regardless of regulations.

Generally, carefully applied safety precautions — pretreatment (e.g., deep stack) to ensure pathogen control, a 15 day withdrawal period before slaughter, not feeding litter to lactating dairy cows, and not feeding litter with high copper concentrations to copper-sensitive sheep — are sufficient to address health concerns. Litter has in fact been used as a feed ingredient for 35 years without any reported adverse effects on human or animal health.

Nutritional Value of Litter

The kind and amount of bedding material used in a broiler house and the number of batches housed on the litter affect the nutritional value of the litter, which should always be tested before being used as a food product for ruminants. The average nutrient contents are as follows:

- **Moisture.** The moisture content of the manure has little nutritional value; but litter that is too dry may be unpalatable, and litter that is too wet may be difficult to handle as a food ingredient. A moisture content in the range of 12 to 25 percent is acceptable.

▼ **Total Digestible Nutrients.** The sum of crude protein and crude fiber values is used to calculate the total digestible nutrients (TDN) in litter. If the litter has a calculated value of 50 percent TDN, it is comparable to hay as an energy source.

▼ **Crude Protein.** The average amount of crude protein in broiler litter is about 24.9 percent. But about 40 percent of that amount is probably nonprotein nitrogen or uric acid. Young cattle cannot use this nonprotein nitrogen as easily as mature cattle can, so broiler litter should only be fed to cattle weighing over 450 pounds.

▼ **Bound Nitrogen.** Insoluble or bound nitrogen occurs in litter that has been overheated. Bound nitrogen is less easily digested than other nitrogen. Average litter samples have 15 percent bound nitrogen; overheated litter may have as much as 50 percent bound nitrogen.

▼ **Crude Fiber.** The fiber source in litter comes mainly from the bedding materials. Ruminants, however, need long roughage, such as hay. At least 5 percent of the litter ration should be in the form of hay or other long roughage.

▼ **Minerals.** Excessive minerals in litter are not usually a problem, though excessive calcium can cause milk fever in beef cows at calving. Withdrawing the litter from the cows' food for 30 days overcomes this difficulty. Microminerals, such as copper, iron, and magnesium, are also present in large amounts. Copper should not be fed at more than 150 parts per million. It builds up in the liver but is usually not harmful.

▼ **Ash.** Ash content is an indication of litter quality and should not exceed 28 percent. For dirt floor houses, about 12 percent of the ash is made up of calcium, phosphorus, potassium, and trace minerals; the rest is soil. Management techniques that reduce the soil content in the litter should be practiced.

Survey of Broiler Litter Composition

In sum, all litter to be used as a beef ration should be analyzed — tested for nutrient content. Litter used for feed should have at least 18 percent crude protein and less than 28 percent ash. Litter that has too much ash is not suitable as a food ingredient. Not more than 25 percent of the crude protein should be bound or insoluble. If broilers are reared on dirt floors, the litter may be contaminated with soil during cleanout.

The number of broods reared on the litter prior to cleanout of the broiler house also affects the quality of the litter; the more broods reared (five or more), the higher the litter is in nutrients.

Charred litter, that is, litter that has been exposed to too much heat during storage and has a burnt wood appearance, is only half as digestible as litter stored in stacks that were protected from excessive heat.

Processing and Storing Broiler Litter

All litter, regardless of its source, should be processed to eliminate pathogenic organisms such as salmonella; pesticide residues; medicated poultry rations such as antibiotics, coccidiostats, copper, and arsenic.

Dead birds may not be composted with poultry litter if the litter is to be used as a feed ingredient.

Litter can be processed by fermentation (ensiled with other feed ingredients such as corn or sorghum), directly acidified, or heat treated. The easiest, most economical method of treatment is deep stacking. Deep stacking should be done for 20 days or more at a temperature of 130°F. Most of the antibiotics approved for chickens are also approved for cows, and deep stacking inhibits molds (mycotoxins). If stack temperatures exceed 140°F, the deep stack should be covered with a polyethylene tarp to exclude oxygen and avoid overheating. Covered litter stacks will reach a temperature high enough to destroy pathogens but not so high that nitrogen digestibility is threatened.

Suggested Rations

Table 1 indicates rations that can be fed to dry brood cows, lactating cows, and stockers. These rations are recommended guidelines, not abso-

Table 1.—Suggested Rations.

RATION NUMBER	1 DRY BROOD COW	2 LACTATING COW	3 STOCKERS
Ingredients	Pounds		
Broiler Litter	800	650	500
Cracked Corn	200	350	500
Total Pounds	1,000	1,000	1,000

lutes, since the nutrient levels in litter are variable. Vitamin A should be added to all rations. Supplementing winter and summer grazing for stocker cattle increases the animals' weight gain and the total beef produced. To reduce bloating, feed the animals Botavec or Rumensin.

Summary

Because ruminant animals can digest forages, other fibrous materials, and inorganic nitrogen such as urea, the use of litter and DPW as a low-cost alternative feed source for these animals is gaining worldwide attention and acceptance. The use of broiler litter will become more widespread as the need for economy and responsible waste management becomes more urgent.

As animal production continues to increase and to concentrate geographically, more waste is produced than can be assimilated by land applications. However, when the litter is properly processed and stored, it can be used as a dietary supplement for cattle resulting in a lower winter feed cost for cattle and a cost-effective way to increase the average daily weight gain of cattle during the stocker production phase — the phase that begins after weaning and continues until the cattle are placed in the feedlot. This alternative to land application helps reduce the environmental risks and adds value to the litter. Since management practices on the farm affect the litter's quality, attempts to market the litter as a feed ingredient begin with a focus on management techniques.

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Horticultural Uses of Litter

Because it has essentially no unpleasant odors, well-composted broiler litter can be used indoors in a soilless potting medium. In fact, its nutrient content makes litter an ideal fertilizer for both indoor and outdoor gardens. It is also a good organic material for improving soil structure and drainage.

Soil Amendment

Gardeners can add composted litter to soils that otherwise contain too much sand or clay to support a garden. Work the top soil loose to a depth of 1 foot; then, spread 3 or 4 inches of compost on the soil. About 2 inches of compost may suffice at a minimum, but in really poor soils, 6 inches can be applied. Turn the soil over after the application to incorporate the compost.

Flower and Vegetable Transplants

Annual and perennial flowers and vegetable transplants also do well in compost-amended settings. Use a trowel to dig a hole in the new location. Remove the plant from its container and tear a hole in the bottom of the root-ball — otherwise, the roots will continue to grow in a tight circle — before setting it into the ground. Fill the hole with amended soil and water thoroughly. Mulching will help the plants retain water, thereby conserving this resource as well.

Transplanting Trees and Shrubs

If you are transplanting trees or shrubs, use the techniques listed above, but make sure that the hole you dig for the plant is at least twice the size of its present container. Work about 3 to 6 inches of composted litter into the soil in the hole and place the tree or shrub therein. Keep as much soil as possible around the root-ball when you take it out of the container. Do, by all means, remove the container, especially if it is plastic, so that the new growth will have plenty of room. The soil line on your plant should be level with your garden. Fill in the hole with the amended soil, and water the plant thoroughly to remove any air pockets that may have been in the backfill.

Potting Mix for Indoor Plants

To make your own potting medium, use equal parts of composted litter and composted pine bark — all living things need nitrogen and carbon. The bark may be screened to remove large pieces (one-half inch or larger) before mixing. Fill the new pot with 1 or 2 inches of the planting medium, spread out the roots of your plant, and set it in the pot. Remove any buds or flowers before replanting to ensure that the plant has time to get properly established. Transplant from one pot size to the next one only; skip one size if you have to, but don't go from a 1-inch pot to a 4-inch pot and expect to succeed. Water the plants in the fall and winter; fertilize them in the growing seasons — spring and summer.

Lawns

Composted broiler litter is a superior product to use to establish new lawn areas. Spread about 2 inches of composted litter on the area to be seeded. Then turn the soil over to a depth of 6 inches to incorporate the material. Place turf on the prepared soil and water it as usual. The addition of compost to the soil helps hold moisture and improves drainage.

Fertilizer

The nutritional analysis of composted litter will vary, depending on conditions of waste production and handling, among other variables. However, most composted litter will have an analysis similar to 2-2-2 commercial fertilizer. That is, it should have no less than 2 percent nitrogen (N), 2 percent phosphorus acid (P_2O_5), and no less than 2 percent potassium as potash (K_2O). Two quarts of broiler litter compost can be applied monthly to your vegetable and flowering plants. It should be worked into the soil lightly — at the drip line or where the water falls naturally from the leaves.

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Other pages in this handbook contain more detailed information on these subjects. Permission is hereby granted to producers, growers, and associations serving the poultry industry to reproduce this material for further distribution. The Poultry Water Quality Consortium is a cooperative effort of industry and government to identify and adopt prudent uses of poultry by-products that will preserve the quality of water for everyone.

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Controlling The Effects of Ammonia and Phosphorus

The effects of ammonia volatilization from litter can be significant at levels above 25 parts per million. It may adversely affect the birds' growth rate, feed efficiency, and egg production; damages the respiratory track; and increases the birds' susceptibility to a variety of avian diseases, including Newcastle disease, airsaculitis, *Mycoplasma gallisepticum*, and keratoconjunctivitis.

Ammonia volatilization from litter also contributes to acid rain. In Europe livestock wastes are considered the dominant source of ammonia pollution in acid rain, and emissions increased as much as 50 percent in the three decades leading to 1980.

Methods to reduce ammonia volatilization from litter usually require good housekeeping, proper ventilation, and perhaps chemical additives. Remediation can be costly but prevention is cost-effective and beneficial to farm workers, poultry, and the environment.

Ammonia emissions from litter during broiler production adversely affect bird health, increase ventilation costs, and cause significant ammonia emissions to the air. Improving nitrogen efficiency by feeding the flock amino acid diets can reduce the content of nitrogen in excrement and help control ammonia emissions.

Ventilating the poultry house before you have a problem; for example, when the house is new, the birds are young, and after cleanouts, is essential. Unless the house is properly ventilated at these times, ammonia problems may be just around the corner. Ventilating to prevent the problem will save growers increased heating and ventilation costs later in the growout.

Another tip: don't let your nose be your sensor. After several years in the poultry business, you may tolerate a higher level of ammonia in the air than is good for you or your operation. First time growers may be sensitive to ammonia at 10 parts per million; seasoned grower's may be unaware of levels as high as 60 ppm. Operating costs, especially for fuel, will be lower at these levels, but so will the birds' performance.

Controlling house humidity will help you manage the ammonia and prevent litter from caking; it will also help control carbon dioxide, dust, and oxygen levels. Humidity in the house should be kept (ideally) at 50 to 70 percent.

Diluting the moist air inside the house with fresh outside air is the key to humidity control, so watch the weather. Warm, humid days will obviously increase the need for ventilation. Because it can be so difficult to gauge how much fresh air is needed, Georgia's Cooperative Extension Service has developed a list of timer settings and number of fans needed to maintain the average humidity in a 40 by 500-foot house during the six or eight weeks of growout (see Tables 1 and 2). You will want to check the weather conditions and perhaps consult with the Cooperative Extension office nearest your facility before adopting these tables.

Two other tips: First, if you are using the tables, consider the timer settings as minimum suggestions when the birds are young. The settings may be adjusted down slightly during extremely cold weather when the birds are older. To help you determine how much leeway you have, an inexpensive relative humidity and temperature gauge will be as useful as more expensive ammonia meters. The difference in

Table 1.—Small Birds (30,000).

BIRD AGE (weeks)	SECONDS ON (5-minute timer)	NUMBER OF 36" FANS
1	30	2
2	60	2
3	90	3
4	120	3
5	150	4
6	180	4

Table 2.—Big Birds (24,000).

BIRD AGE (weeks)	SECONDS ON (5-minute timer)	NUMBER OF 36" FANS
1	30	2
2	60	2
3	60	3
4	90	3
5	120	3
6	120	4
7	150	4
8	180	4

price will be significant: $30 as opposed to $1,500, and the ammonia meter may not last more than a year or two in a poultry house.

Second, be sure to check the drinker line height and pressure. Adding additional water to the house through improper drinker operation will skew the tables and cost you money. It takes about 12,000 cubic feet of air to get rid of a gallon of water. So wasting five gallons of water, will increase your ventilation rates by 1,000 cubic feet per minute. If the fresh air also has to be heated, you will probably use an additional half-gallon of propane per hour.

Phosphorus runoff from fields and ammonia entering the air are two problems associated with poultry litter. The amount of water soluble phosphorus in litter varies depending on its source and management. For example,

- fresh broiler litter contains 1.23 grams of water soluble phosphorus per kilogram of litter,
- stacked litter, 2.29 grams;
- dead bird compost, 2.15 grams;
- caged layer manure, 2.68 grams; and
- turkey litter, 3.02 grams.

The addition of alum (aluminum sulfate) has been reported to reduce ammonia levels in the house and to decrease phosphorus runoff when the litter is spread on pasture. The reduction in phosphorus runoff have been as high as 87 percent.

Other litter additives are available in addition to alum that, by acidifying the litter, are reported to decrease the levels of ammonia in the air of poultry houses. Alum is the only one that is reported to also reduce phosphorus runoff when the treated litter is applied to the land. The acidification of the litter is also reported to reduce the levels of bacteria in the litter thus having a potential food safety benefit.

Concerns have been expressed over the safety of workers applying alum to the litter. As a result, the manufacturer now supplies it in a low-dust granular form and suggests the use of goggles and particle dust masks by the individual applying the alum to the litter.

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An Overview of Poultry Mortality Management

Responsibility for the safe and nonwasteful management of dead birds — a challenge for the poultry industry — is a practical problem that growers face on a near daily basis. It begins with choosing the best method for the proper disposal of the carcasses. Because dead birds constitute a large portion of the total wastes generated in poultry production, their disposal must be biologically secure, environmentally safe and cost effective.

Most normal mortalities occur during the first and last two weeks of the growing cycle for broilers and from 10 to 13 weeks of age for layers. Normal mortality for broiler production is 3 to 5 percent over the production cycle or about 0.1 percent per day. Thus, for example, in a flock of 100,000 broilers grown 49 days, as many as 5,000 may die. A single grower, assuming that a typical broiler house holds 20,000 birds weighing 2 to 4 pounds, may have as many as 85 pounds of dead birds to dispose of each day near the end of the growing cycle. A roaster operation may have to dispose of as many as 115 pounds per day, and a turkey operation may dispose of 150 to 200 pounds per day.

Mortality rates in other kinds of poultry operations will be similar to or somewhat lower than the rate for broilers. The exact number of daily mortalities will vary depending on the number of birds on hand as well as their size and age. Massive die-offs, catastrophic losses, and spent (unproductive) hens are additional challenges.

Burial in specifically designed pits, incineration, and rendering are the most common methods of disposal, though environmental, economic, and practical concerns have fueled interest in composting as a fourth alternative. Each of these methods is supported by best management practice guidelines. Newer technologies, for example, small-bin composting, fermentation, and refrigeration, are also emerging in field trials as individuals, the industry, and agricultural researchers seek to meet the challenge of mortality management.

Burial Pits

Burial pits are not always practical and may not always be permitted. The earliest burial pits (which were only adequate for very small operations) were simply holes dug in the ground with a small opening at the top. Depending on geologic and weather conditions, such pits will almost certainly affect water quality. Therefore, for many poultry producers, they are no longer an option given the intensity and concentration of today's industry. Where burial pits are still allowed, they generally require a permit and must be properly "constructed," sized, and located. They must also be tightly covered for safety and to prevent odors.

Incineration

Incineration is an acceptable and popular alternative to the use of burial pits. It is also biologically safe (the burning destroys pathogens), and poses no threat to surface or groundwater though care must be taken to insure that smokestacks do not create air quality problems or nuisance odors.

Historically, incineration has been the most costly method of mortality disposal. However, a new generation of improved incinerators may defeat this obstacle, particularly since the newer equipment also complies with air quality standards.

The Composting Alternative

Composting dead birds emerged as an acceptable method of mortality disposal only in the 1980s. Composting, however, is an ancient and natural waste-management technique that continued to be practiced with little change throughout the 18th and 19th centuries. In all that time, composting methods and speed differed little from the decomposition of organic matter that occurs naturally. The current use of composting as a managed method of mortality disposal improves on that technique to fulfill the biological, environmental, and cost criteria that must be met to qualify as an approved method. Pathogens cannot survive the increased temperatures associated with composting, odor and insects can be controlled, and air and water quality are protected. As an additional advantage, composting results in an inoffensive and value added end product that can be stockpiled until needed as a fertilizer or soil amendment. Each carcass is, in fact, 2 to 9 percent nitrogen, 1 to 4 percent total phosphorus, and 1 to 7 percent total potassium.

Rendering

Rendering may be the safest way to dispose of mortalities, at least from an environmental point of view. It, like composting, adds value to the end product — in this case, the carcasses are processed into biologically safe, protein and nutrient-enriched feed-mill products, such as feather meal and other dietary supplements for poultry and other animals.

Major drawbacks to rendering are the difficulty of transporting the carcasses to the renderer's plant while they are still fresh, and concern that disease or disease-causing organisms might be picked up in the vehicle or at the rendering plant and unintentionally returned to the farm.

On-farm fermentation offers growers a way to preserve the carcasses until they can be delivered to the renderer. The carcasses are collected, put through a grinder and mixed with a carbohydrate. Bacteria common in the birds' intestines ferment the carbohydrate to lactic acid, which neutralizes pathogens but preserves the nutrients, thus permitting the product to be held a longer time on the farm. Refrigeration or freezing is another method to preserve dead birds prior to their delivery to a rendering plant.

Decision Criteria

Growers must carefully consider the trade-offs — the differences in resource requirements and outcomes involved in these mortality management practices — and the effect of local conditions and personal preferences to determine the method of mortality management that best fulfills their need. Table 1 compares the methods by cost and in relation to size, environmental concern, and marketing considerations. Other characteristics may be important to some growers.

In all cases, unsanctioned methods, such as feeding the carcasses to hogs or other domestic animals or abandoning them in sinkholes or creeks or in the wild, should not be attempted. Nor can dead birds be delivered to municipal landfills. Dead bird disposal is a potential health hazard and a regulated activity. Growers must choose the permitted disposal method that best suits their management style and perform it according to strictly maintained standards to ensure sanitary conditions and the least possible environmental consequences.

Growers should check with their state agencies (environmental, agricultural, and animal veterinary medicine) to be certain that their plans comply with all dead animal disposal regulations. The USDA Natural Resources Conservation Service and Cooperative Extension Service offices can be of assistance.

More detailed discussions of burial pits, incineration, rendering, and composting as methods for managing dead birds can be found in subsequent fact sheets in this section of the handbook.

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Table 1.—Characteristics of Dead-Bird Disposal Systems.

Item	Disposal Pit	Incineration	Large-Bin Compost	Small-Bin Compost	Fermentation	Refrigeration
	EXISTING TECHNOLOGIES				EMERGING TECHNOLOGIES	
Initial investment cost	M	L	M	L	H	H
Variable cost	L	H	M	M	M	H
Fixed cost	M	L	M	L	M	H
Value of by-product	N	N	H	H	M	M
Net cost	L	H	M	L	M	H
Cost sensitivity to size	L	L	H	L	H	L
Flock size limitations	L	M	L	H	L	L
Environmental concern	H	M	L	L	N	N
Market constraints	N	L	N	L	H	H

KEY: H=high M=medium L=low N=none

Adapted from Crews, Donald, and Blake, 1995.

Other pages in this handbook contain more detailed information on these subjects. Permission is hereby granted to producers, growers, and associations serving the poultry industry to reproduce this material for further distribution. The Poultry Water Quality Consortium is a cooperative effort of industry and government to identify and adopt prudent uses of poultry by-products that will preserve the quality of water for everyone.

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Burial — A Disposal Method for Dead Birds

The burial of dead birds in trenches, open pits, and landfills is rarely an acceptable method of dead bird disposal. In Arkansas and Alabama, no new in-ground burial pits are permitted — and states that do permit them consider this option the least desirable method or the method of last resort for mortality management. Until recently, however, burial was the only practical method some growers had to dispose of their dead birds — despite its potential for water pollution. Its use is now hedged with various guidelines and restrictions, such as construction requirements, loading rates, and setback distances from water resources, residences, and property lines. In all cases, the pits must be fabricated.

Pit Design and Fabrication

A fabricated burial pit is an open-bottomed, reinforced hole in the ground that has one or more openings at the top through which carcasses are dropped. An airtight cover above the openings prevents odors from escaping. The pit provides an environment in which aerobic and anaerobic microorganisms can consume most of the organic material. Only the feathers and bones should be left. Although disposal pits require minimal labor and supervision, they must be maintained in a sanitary, legal, and socially acceptable manner.

Fabricated pits should be made of concrete block, poured concrete, or treated timbers. Some prefabricated pits can be purchased from septic tank dealers and delivered to the farm ready for installation. Under no circumstances, however, should the pit be simply a hole in the ground dug with a backhoe and lined with tin. The decomposition process will produce very little water inside the pit, but the pit should be covered with soil and planted to vegetation to carry water away from the pit and to protect it from access by heavy equipment.

The openings — also called drop chutes — are made of plastic (PVC) pipes, which protrude out of the mound at intervals of five feet. The chutes should have tightly fitted but removable covers. The bottom of the pit is earthen with holes at intervals up the sides.

Location

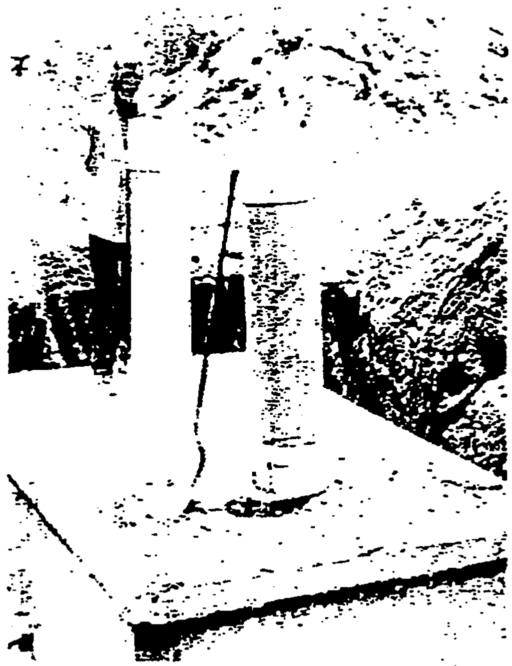
Location guidelines established by state agencies to protect water resources should be carefully observed. Generally, a disposal pit should be located at least 200 to 300 feet from dwellings and the nearest water well, 50 feet from property lines, 25 feet from the poultry house and 100 to 300 feet from any flowing stream or public body of water.

Before constructing a disposal pit, make certain that the soil composition is acceptable. Bedrock (especially limestone) and sandy soils should be avoided. Locate pits in soil where good surface runoff will occur. Sandy soils are not suitable for pit installations.

To prevent groundwater contamination, the pit's lowest point should be at least five feet above the highest known water table and at least five feet above bedrock to keep contamination from traveling along a rock fissure. To prevent water from seeping into the pit, construction on a slope, floodplain, or low-lying area should be avoided and in some states is not permitted.

Pit Size

The pit itself should be at least six feet deep with reinforced walls. Its size will depend on several factors, including the expected mortal-



Properly constructed disposal pits are made of concrete block, poured concrete, or treated timbers.

ity rate of the flock, bird size, and environmental conditions. Use the following table to estimate pit size:

TYPE OF MORTALITY	PIT SIZE IN CUBIC FEET PER 1,000 BIRDS
Broilers	50
Turkeys (to 18 weeks)	100
Layers (commercial)	55

For broiler mortalities, for example, if you have a 5 percent mortality rate in a flock of 20,000 and you raise five flocks per year, your burial pit should contain at least 250 cubic feet of disposal space. That is, it should be about six feet deep, six feet wide, and about seven feet long. Sometimes it can be more convenient to use several smaller pits to prevent overloading. In cooler climates, the pit size should be larger to accommodate a slower rate of decomposition. Keep in mind that some states may have maximum loading rates depending on the area's vulnerability to groundwater pollution.

Durability and Cost

The life of the pit will depend on its location and whether it is properly sized, constructed, and managed. To ensure total decomposition, the pit must be operated efficiently to protect the bacterial population. High acidity, for example, will retard the decomposition of dead birds. Disposal pits are most efficient during warmer months when bacterial action is greatest. Decomposition is slowed by winter temperatures or by accumulation of water in the pit. Grinding the carcasses or splitting open the dead birds (puncturing the abdominal cavity) will expel gases, increase the pit's efficiency, and extend its life.

The cost of constructing disposal pits varies widely depending on the materials used, site conditions, and the size of the pit. Geologic conditions — rocky soil, for example — can make digging expensive. As pit size increases, heavier construction is required for walls and tops; thus, higher costs are incurred. For a well-built pit, a useful life of five years is not uncommon, and some producers have reported that pits can be useful for eight to 10 years. Replacement is required when the pit is full.

Operation

After a pit is constructed, producers should check their facilities twice daily for mortalities and transfer them immediately to the pit. (Current law requires dead animals to be properly disposed of within 24 hours.) Covers on the drop chutes should be kept closed at all times to prevent odor and restrict access by children, animals, and rodents. Certain insects in a disposal pit are beneficial to the decomposition of the carcasses, but insects should not be allowed to develop into a nuisance. With proper handling the disposal pit costs nothing to maintain except for the labor of collecting the carcasses.

Drawbacks

Burial pits may attract flies and scavengers, and they may emit offensive odors. Further, today's farm may have insufficient land space for burial pits, or the capacity of the pits may be limited in winter. If the oxygen supply is insufficient, the decomposition process will be arrested. Slacked lime can be added to the burial pit to break down the tissue of the dead birds. It will also, in effect, sterilize the remains. If the site has poor soils or a high water table, groundwater pollution is a distinct possibility.

Before constructing or installing a prefabricated disposal pit, poultry producers should consult with their state's veterinary specialist, other agricultural offices, and environmental or natural resource agencies. These agencies may regulate the use of burial pits or disallow their use entirely, so seeking expert guidance before production begins often saves time and money. Local USDA Natural Resources Conservation Service or Cooperative Extension Service offices can provide technical assistance to growers who want to use disposal pits as part of their mortality management plans.

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Incineration — A Disposal Method for Dead Birds

Incineration, or cremation, is a safe method of carcass disposal and may be the method of choice in areas plagued by poor drainage and rocky soils. The major advantage of incineration is its ability to curtail disease. It is biologically secure, and it does not create water pollution problems. Even its by-product — ashes — is minimal, easy to dispose of, and unlikely to attract rodents or pests.

On the other hand, incinerators can be a costly item to install and operate and are expected to become more expensive as fuel costs rise. Further, while incineration destroys pathogens and poses no risk to water, its effect on air quality must be carefully monitored by poultry growers who choose this method of mortality management.

Incineration is not, then, a casual or inexpensive undertaking. Barrels or other homemade vessels are unsatisfactory burners and have serious consequences for the grower if they result in air pollution or unpleasant odors. Using incineration to manage poultry mortalities must be carefully planned: it must comply with dead animal regulations, meet all air quality standards, and justify investments in commercial equipment and the risk of increasing energy costs.

Notwithstanding these drawbacks, incineration is biologically the safest method of mortality management and simultaneously the method most likely to protect water resources. Producers considering this method of mortality management should consult with their state's agricultural, environmental, and veterinary medical agencies on the best way to incorporate this method. Agricultural incinerators do not generally require a permit, but they are designed to handle Type 4 wastes (e.g., animal remains, carcasses, organs, and solid tissue from farms and animal labs), but not other wastes (e.g., plastics and other organics).

Good Incinerator Design

A variety of commercial incinerators are available, and each one should be installed according to the manufacturer's specifications and local codes — typically outside, but under a roofed structure and away from any combustibles.

Incinerators should be sturdily built and able to accommodate daily mortalities. Indeed they should be sized to handle large loads and high temperatures; however, very large-scale loads, for example, loads running over 100 pounds per hour may require an operating permit. Growers should carefully estimate the capacity needed to manage daily mortalities and include other disposal methods in their resource management plans to cover situations in which heavy, unexpected losses can occur.

A variety of commercial incinerators are available.

An incinerator's material qualities are unlikely to become a problem if the unit is bought from a reputable dealer since stainless, aluminized, or heat-tempered steel is commonly used in their construction. Insulated models and those with heat shields may save energy and minimize the unit's exterior temperature. Those that have automatic controls will be more convenient and perhaps more economical.

Location and Operation

Incinerators should be used daily, so putting them in an area convenient to the poultry house will contribute to better management. Sheltering the incinerator from inclement weather will extend the life of the unit. For best results, it can be placed on a concrete slab.

To avoid nuisance complaints, locate the unit downwind of the poultry house, residences, and neighbors' residences. Finally, always check that the discharge stack is far enough away from trees or wooden structures to avoid fires, since incinerators burn at intensely high temperatures.

Incinerator Costs

Cost is no doubt the chief factor limiting the use of incineration in mortality management. The total investment includes the initial purchase, subsequent maintenance, and the interplay between the rate of burn and the price of fuel. Equipment costs vary depending on the size and type of the incinerator. Afterburner devices that recycle the fumes will help control odors and dust but will likely be priced as accessories. Expendable parts and grates will also need to be replaced periodically — perhaps every two or three years — and the whole system may need replacement (or overhaul) every five to seven years.

The rate of burn will vary depending on the weight, moisture, and fat content of the carcasses and on the loading capacity of the unit (e.g., incinerators may have to be loaded several times to handle a day's mortalities). Assuming an average burn rate of about 65 pounds per hour (based on past experience), and a fuel cost of $0.61 per gallon, a grower will expend $3.50 per day to incinerate 100 pounds of mortalities (1990 estimates). If fuel prices increase, so will the cost of each day's burn.

Growers have for the most part been unwilling to risk the high costs involved in this process, since they have no control over the price of fuel, and because the choice of incineration also means the loss of any nutrient value that the mortalities might have had if composted for land applications or rendered for other uses.

New technology may be the key to changing attitudes about incineration. Influenced by technological advances, current manufacturing specifications are producing a generation of incinerators that last longer, control emissions better, and burn more efficiently than older models in the field. Simply put: the new performance standards make it possible to separate the cost of incineration from the rising price of fuels. Thus, for example, trials on newer models have accomplished the same daily burn for less money than for older incinerators, even though fuel rates used in the computations were higher than those actually charged in 1990.

Incineration is an acceptable and safe method of poultry mortality management. It does not risk the spread of disease or water pollution. If, as now seems likely, technology succeeds in controlling its cost and its air emissions, incineration will become more competitive among the various methods available for managing this aspect of production. Growers considering incineration as a method of poultry mortality management are encouraged to plan this action in connection with their entire resource management system.

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Composting — A Disposal Method for Dead Birds

Composting poultry mortalities or dead birds is a relatively new, practical, and sanitary alternative to burial pits and incinerators. It is an economical, fairly odorless, and biologically sound practice for broiler, turkey, layer, and Cornish hen operations. Management commitment is the key to successful composting.

Composting resolves the disposal problem and yields a valuable product — a reduced odor, spongy, humus-like material that has several marketable uses ranging from soil conditioner to horticultural growing medium. Some states may require that composted birds be applied to the grower's own land; even so, composting has other values:

- Composting is environmentally sound; properly done, it decreases the potential for surface and groundwater contamination.
- Composting destroys disease-causing organisms and fly larvae.
- The materials needed for composting — mortalities, litter, and sometimes straw and water — are readily available.
- Once a composting system has been set up, it will not require much labor; and
- Compared to other options, composting is not a costly method of mortality disposal.

A Natural Process

Composting is a controlled, natural aerobic process in which heat, bacteria, and fungi fueled by carbon, nitrogen, oxygen, and moisture decompose organic waste, changing it into a stable product.

The grower's tasks are to collect the carcasses and place them in alternating layers with the manure and straw (or other carbon source); and to monitor the process to ensure that enough heat is being generated to complete the process of decomposition. The grower will also turn the composting mixture, usually by moving it from one bin into another. Turning the compost ensures that the entire mass is sufficiently aerated.

Composter Design and Operation

Composting poultry mortalities can be done in or outside the poultry house, but it should always be done in an environmentally safe and healthy manner, under a roof, and protected from rain, stormwater, or surface water flow. Most poultry mortalities will be composted in a facility housing a two-stage large bin composter. A typical two-stage large bin composter is designed as follows:

- The size of the primary bins is determined by the following equation:

  V = flock size x (rate of mortality / total number of days) x average market weight x 2.5 cubic feet

  The secondary bins should be equal to, or larger, than the primary bins, since experience teaches that one cubic foot of primary bin and one cubic foot of secondary bin is needed per pound of daily mortality.
- The height of bins should not exceed 5 feet. Heights greater than 5 feet increase compaction and the potential for overheating.
- The width of the bins is usually selected to accommodate the loading equipment. A width of 8 to 10 feet is normal, but the bins could be wider.

- The depth of large bins is not restricted, assuming that the operator has appropriate mechanized equipment to manipulate the compost from front to back. Deeper bins are more difficult to enter and exit and take more time to work. Secondary bins can be larger, but they must have the same capacity as the primary bins (see Fig. 1).
- Extra primary bins will provide useful storage for litter and straw. If high mortalities occur, these bins could be used for composting.
- The ceiling height of the composter should be high enough to accommodate a front-end loader extended upward.

The decision to use a composting system for poultry mortality management means that the grower is committed to managing the composter facility properly and seeking help as needed. Once the composter bins have been adequately designed, the building itself should be considered. A few general principles apply to the composting facility.

- **Location and Access.** The composting facility should not be located near any residence. Offensive odors are possible during the composting process; and the handling of dead birds, manure, and litter on a daily basis may not be aesthetically pleasing. The site should be well drained and accessible; farm equipment is usually needed to carry dead birds and compost ingredients to the composter and to remove the finished compost.
- **Foundations.** An impervious, weight-bearing foundation or floor, preferably of concrete, should be provided under primary and secondary composting bins. Experience has shown that after frequent loading and unloading activities, dirt or gravel tends to become rutted and potholed. A good foundation ensures all-weather operation, helps secure against rodent and animal activity, and minimizes the potential for pollution of surrounding areas.
- **Building Materials and Design.** Pressure-treated lumber or other rot-resistant materials are necessary. A roofed composter ensures year-round, all-weather operation, helps control stormwater runoff, and preserves composting ingredients. Adequate roof height is also needed for clearance when using a front-end loader.

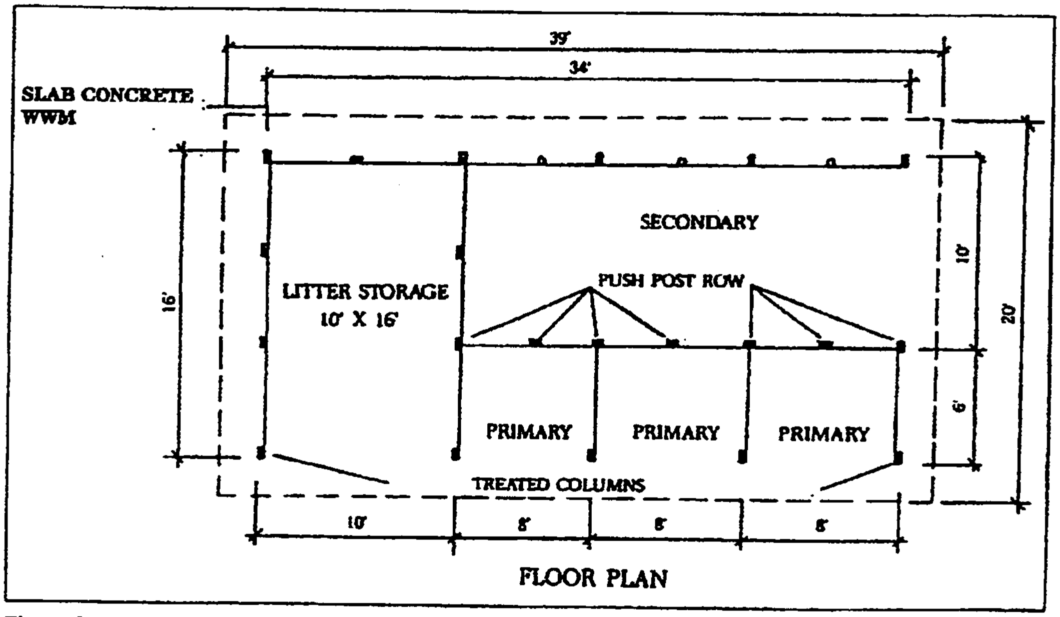

Figure 1.—Typical two-stage composter floor plan (not to scale).

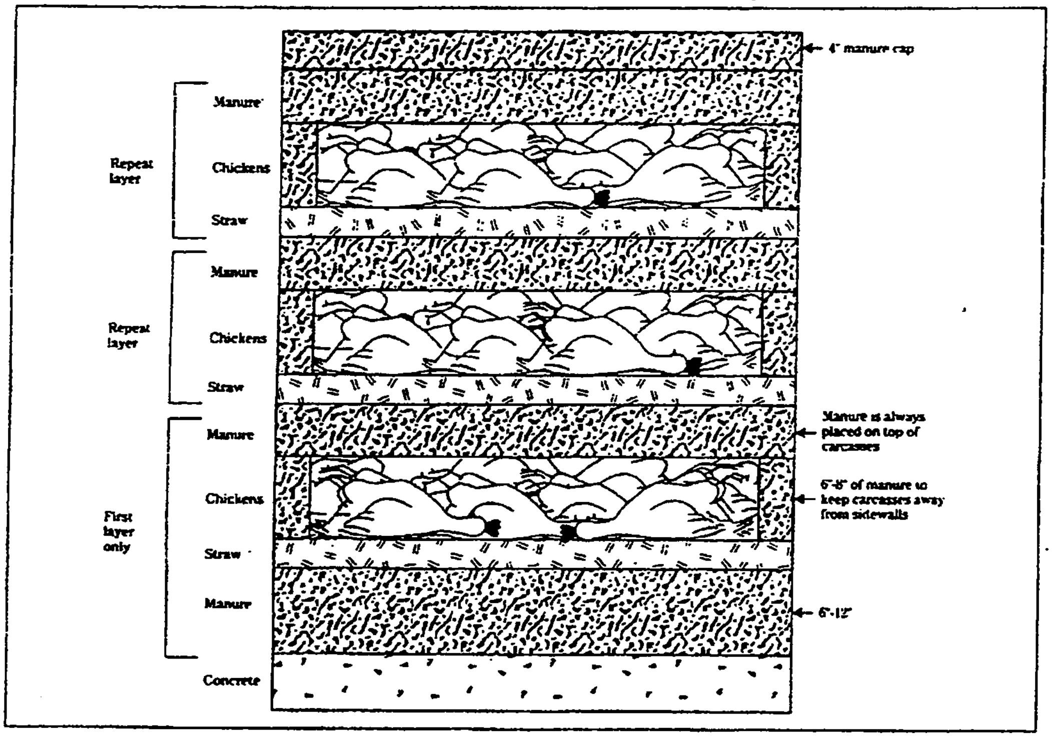

Figure 2.—Recommended layering for dead bird composting.

The amount of rain that is blown into the composter can be minimized by the addition of partial sidewalls or curtains and guttering along the roof.

Composting Recipe and Method

For composting poultry mortalities in a two-stage composter, a prescribed mixture of ingredients is used called a "recipe." The recipe calls for dead birds, litter, straw or other carbon source, and water (Table 1). Recipes for a single-stage composter differ slightly.

Proper layering of the recipe will ensure appropriate heat (from microbiological activity) for composting the mortalities in about 14 days. To begin, place 6 to 12 inches of litter or manure, followed by a 6-inch layer of loose straw to provide aeration, followed by a layer of dead birds. Depending on the moisture content of the manure or cake, water may or may not be added. Repeat this layering process until the pile or bin is full (see Fig. 2).

Table 1.—Typical recipe for composting dead birds with litter, straw, and water as ingredients.

INGREDIENTS	PARTS BY VOLUME
Dead Birds	1.0
Litter	1.5
Straw	0.5 – 0.75
Water	0.0 – 0.5

Water as an ingredient may not be necessary. Too much water can result in anaerobic conditions. An alternate recipe uses 1 part birds with 2 to 3 parts of litter cake (i.e., litter having a high moisture content).

Leave 6 to 8 inches of space between the edges of the dead bird layer and the wooden wall of the composter. This space allows air movement around the pile and keeps carcasses nearer to the center of the pile, where the heat is highest. Do not stack dead birds on top of each other. They may be adjacent to one another, even touching, but they must be arranged in a single layer. Spread litter or manure and straw as evenly as possible.

Use the same layering sequence (dead birds, litter, and straw) after loading mortalities that only partially complete a layer. If dead birds are carelessly loaded — stacked one on another or placed against the sidewalls of the structure — they will putrefy. Once the compost pile is complete, or full, "cap it off" with a 6-inch layer of dry litter, manure, straw, or similar material to reduce the potential for attracting flies and to provide a more pleasing appearance. This same recipe can be used for composting caged layers, broilers, turkeys, breeders, or other types of poultry.

Mixing, aerating, and moving the composting mass with a front-end loader or shovel will uniformly distribute the ingredients, add oxygen to the pile, and reinvigorate the composting process. Temperatures will rise after each mixing until most readily available organic material is consumed. After the pile is capped, wait 11 to 14 days before turning the mixture. However, if the temperature falls below 120 °F or rises above 180 °F, the compost pile should be aerated or mixed immediately.

Successful composting requires a specific range of particle sizes, moisture content, carbon-to-nitrogen ratio, and temperature. The following general rules apply:

- **Particle Size.** Particles that are too small will compact to such an extent that air movement into the pile is prevented. Material that is too large allows too much exchange of air, and so prevents the heat from building up properly. A proper mixture of size allows both air exchange and temperature buildup.

- **Moisture Content.** The ideal moisture content in the composting pile ranges from 40 percent to 60 percent. Too much moisture can cause the pile to become saturated, which excludes oxygen. The process then becomes anaerobic, a condition that results in offensive odors and attracts flies. Runoff from a composter that is too wet can pollute the soil or water. Too little moisture reduces microbial activity and decreases the rate of composting.

- **Carbon-to-Nitrogen Ratio.** Carbon and nitrogen are vital nutrients for the growth and reproduction of bacteria and fungi; therefore, the ratio of carbon to nitrogen (C:N) influences the rate at which the composting process proceeds. Conditions are most ideal for composting when the C:N ratio is between 15:1 and 35:1.

  If the C:N is too high, the process slows down because it has insufficient nitrogen. This imbalance can be corrected by adding more manure or litter to the compost pile. If the C:N ratio is too low, the bacteria and fungi cannot use all of the available nitrogen, and the excess nitrogen will be converted to ammonia, resulting in unpleasant odors. This problem is fixed by adding more straw or sawdust.

  More recent experience has shown, however, that composting poultry mortalities results in a partial compost. Hence, maintaining the exact carbon-to-nitrogen ratio, while important, is not critical. Many recipes now reduce or eliminate straw entirely, substituting cake, as previously noted, or even the composted product. In fact, 50 percent of the contents in the secondary bin can be input with a new batch of mortalities in the primary bin. This practice reduces the amount of compost that will need to be land applied by 50 percent.

- **Temperature.** The best indicator of proper biological activity in the composter is temperature. Use a probe-type 36-inch stainless steel thermometer, 0 to 250 °F, with a pointed tip to monitor temperatures within the compost pile. Optimum temperature range is 130 to 150 °F. When the temperature decreases, the general problem is that not enough oxygen is available for the bacteria and fungi. Oxygen can be replenished by turning or aerating the pile. Temperatures will rise as the composting process repeats itself.

  The cycle of composting, turning, composting can be repeated as long as there is organic material available to compost and the proper moisture content and C:N ratio are present. When temperatures reach the optimum range for three days, harmful microorganisms (pathogens) and fly larvae will be destroyed. Daily recording of the temperatures in the piles is important because it will indicate whether the bacteria and fungi are working properly.

Financial Considerations

Costs of composters depend on many factors — size, configuration (e.g., work areas, ingredients, and finished compost storage), and utilities. Some composting structures have been built for as little as $500; others, for as much as $50,000. No specific plan or layout for composters works best in all cases. Many different designs will perform adequately, but management capabilities determine the success of the composting process. Standard plans and management information for poultry mortality composters are available through local USDA Natural Resources Conservation Service or Cooperative Extension Service offices.

Financial aid or cost-share funding may be available to help pay for the design and construction of composting facilities. Check with your local conservation district, USDA Natural Resources Conservation Service, or Cooperative Extension Service offices to learn more about these programs.

Changes in the recipe and design of composters are an indication that this practice is still in development, and further refinements can be expected. In the meantime, the composter designs now available can be used not only to deal with routine mortalities, but also for catastrophic losses. Growers interested in using this mortality management approach are urged to contact the appropriate local, state, and federal agencies for assistance.

Composting Catastrophic Event Mortalities

Composting large numbers of poultry mortalities after a catastrophic event is relatively simple and inexpensive, and should be considered over burial for water quality protection. The process is the same as for normal mortality numbers, but without the bins.

Catastrophic mortality can be composted in the bedding or litter where the poultry were housed if the whole population is involved and adequate space and time are available, or they can be composted outside. Prior planning is necessary to ensure that the materials needed to build the composting pile or windrow (especially the bulking agent, sawdust, wood chips, or straw) will be on hand.

When composting catastrophic mortalities in a windrow, allow at least one cubic foot of bulking material per 10 pounds of expected mortality (e.g., 1,000 birds at three pounds each would require 300 cubic feet of bulking material); and size the windrow according to need. A window 12 feet by 6 feet high will hold approximately 300 pounds of mortality. Thus, 1,000 birds at 3 pounds each would require a windrow 3 feet long with appropriate end cover; and the materials needed per cubic foot of windrow length (300 pounds of mortality) would be 400 pounds of litter and 700 pounds of sawdust or other bulking agent.

Nine steps are needed to build a windrow:

- select a well-drained site;
- make a bed layer of wood chips 12 inches thick and 12 feet wide for the length of the windrow;
- add a 4-inch layer of fluffed straw as a base;
- deposit an 8 to 10 inch layer of mortalities, but stop about a foot from the edge of the lower layer;
- spray the mortalities with enough water to saturate the feathers;
- deposit a six-inch layer of sawdust or other bulking agent to the width of the birds; and
- repeat steps three to six as needed. Then,
- starting from the bottom, cover the entire pile with a layer of sawdust, two to four inches thick; and
- add to the length of the windrow as more mortality develops.

To maintain the windrow:

- use a long-stemmed thermometer to ensure that the temperature is rising — it should reach 135 to 145°F within a week —
- as the temperature declines (after 7 to 10 days) to 115 to 125°F, turn the windrow;

- in turning the material, be sure to lift and drop it in place (rather than merely pushing it) to form a new windrow;
- add water if the material is too dry (does not leave your hand moist when squeezed), or sawdust, if it is too moist (drips more than two drops in your hand); and
- cover any exposed carcass tissue in the new windrow with more sawdust.

After an additional three or four weeks the compost can be added to manure in storage for land application.

Because the poultry industry is so often concentrated in a geographic region, there can be many opportunities for recycling the by-products of production, including normal and catastrophic event mortalities. Composting normal and catastrophic poultry mortality on the farm can save transportation fees and tipping costs, reduce the potential spread of pathogenic diseases, and prevent groundwater pollution from burial practices.

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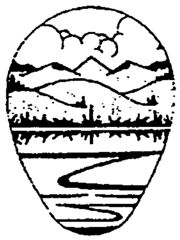

Mortality Composters — Small Bins, Minicomposters, and Packaged Deals

The composting process used in two-stage composting (see PMM / 4) can be adapted to fit various poultry operations and management styles. Mortalities are unavoidable whether the birds — or the operation — are large or small; but not all growers have the same access to mechanized equipment.

Small Bin Composting Systems

Small bin composters are two-stage composters developed for use on farms with limited equipment. Size of the primary bins is limited, primarily by the reach of the loader; so how many bins there will be is determined by how many are needed to dispose adequately of the mortalities. The secondary bins must be equal in capacity to the primary bins, but may be fewer in number than the primary bins and larger — they may be, and often are, twice the volume of the primary bins.

Recall the equation (in PMM / 4) for determining the size of the bins in the large bin composter:

V = flock size x (rate of mortality/total number of days) x average market weight x 2.5 cubic feet

The same equation can be used to size the small bins. Growers using limited equipment will probably want to build smaller bins. That is, they will build as many small bins — each about 5' x 5' x 8' — as they need to reach the required volume.

Table 1 illustrates this equation. It shows the number of primary bins that broiler growers will need depending on the size of their flock, the birds' weight and the volume in the bin for flocks ranging from 20,000 to 200,000 broilers.

Minicomposters

Growers raising fewer birds and wanting to use only hand labor may prefer another composting style. The advantage of using smaller minicomposters is that adequate decomposition of the birds can be completed in one cycle, so no secondary bins are required. These really small in-house composters, which can simply be pallets tied together to make a three-sided cubicle or box, do not even require floors. These bins can be constructed to approximate a 4' x 4' x4' cube. Litter from the previous flock is spread on the floor of the cubicle, then a single layer of birds are covered with twice that volume of litter (a two to one ratio). The composter should be capped off before a new bin is opened for the next flock. The compost can be land applied when the live birds are marketed. This composter can be placed either within the growout facility or outside the growout facility under a separate roofed building.

In-house composters can also be made using four screen-and-lumber panels (about 40' x 36') to construct a single square bin (Fig. 1). Each bin has a capacity of up to 30 pounds of dead birds per day or a total capacity of 600 pounds. Four to six such bins will handle the dead birds from a 20,000-bird broiler house at a cost of about $500. Position assembled bins at a location convenient for gathering the dead birds and for easy access for unloading between flocks.

Packaged Composters

Packaged or manufactured composters offer yet another way that poultry growers can improve on this ancient technique for handling organic waste. Growers who use prefabricated composters can collect the composted material

Table 1.—Number of First Stage Composter Bins Required for Broilers Using 5ft x 5ft x 8ft Bins.

NO. OF BROILERS	LBS. DEAD/DAY ON DAY 50* —lbs—	VOLUME IN 1st STAGE** —cf—	NO. OF BINS IN 1st STAGE
20,000	67	168	2
40,000	134	335	2
60,000	201	503	3
80,000	268	670	4
100,000	335	838	4
120,000	402	1,005	5
140,000	469	1,173	6
160,000	536	1,340	7
180,000	603	1,508	8
200,000	670	1,675	8

* Assumes mature weight of 4.2 lbs; flock loss of 4% or 0.8 bird/day/1000.
** (Total weight loss near maturity) x (2.5 cf/lb dead wgt) = volume storage required.

Source: USDA Composting Facility Guide.

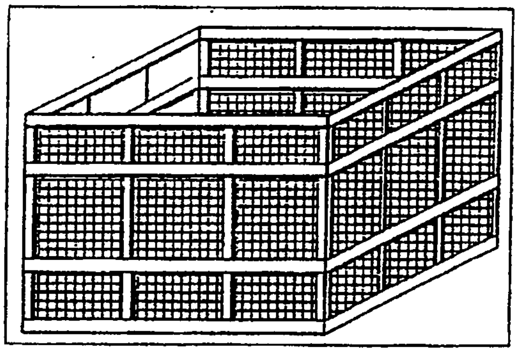

Figure 1.—Typical in-house composter.

that lies in the bottom of the box and shovel, or recycle, it back into the top. The compost, in effect, is substituted for the manure or litter used in the two-stage and minicomposters. Peanut hulls or other material can be added if a bulking agent is needed to supply oxygen, and a small amount of new litter can be added periodically to ensure the right carbon to nitrogen ratio. Recycling the compost, which can also be done in two-stage composters, has an additional environmental benefit: it can reduce by as much as 50 percent the amount of composted material to be land applied.

Prefabricated composters, which should be used according to the manufacturer's specifications, are primarily used by broiler growers producing up to 50 and 60 thousand birds. To reduce compaction and oxygen depletion, the loading rate per day should be reduced as the weight of the birds increase, and at maximum capacity, only two layers of birds should be placed in the composter each day — one layer is preferred.

Operating a Minicomposter

The process for composting in a single-stage, or minicomposter, begins with layering the recipe. The start-up materials are 200 pounds of litter, one-third bale of straw (though some find that straw is not necessary for effective composting), and 15 gallons of water. Add the ingredients to the bin in the following order: 6 inches of loose straw, 65 pounds dry litter, and 5 gallons of water. Repeat the layering process three times until all start-up ingredients have been used. Check the temperature by inserting a thermometer; when the material reaches 140 to 150 °F, the composter is ready to begin processing dead birds.

Form a V-shaped 18-inch deep trough in the center of the bin. Add straw, dead birds, litter, and water and cover or cap with start-up ingredients. Avoid placing dead birds closer than 6 inches to the walls. Mixing and aeration take place when the bin is prepared for the next load of dead birds (Fig. 2). Loading rates should not exceed 25 pounds per day per minicomposter. Record the temperature at a depth of 8 to 20 inches in the center of the pile daily. Repeat this procedure until the bin is filled. Thereafter, compost from prior operations can be used in place of new materials to restart.

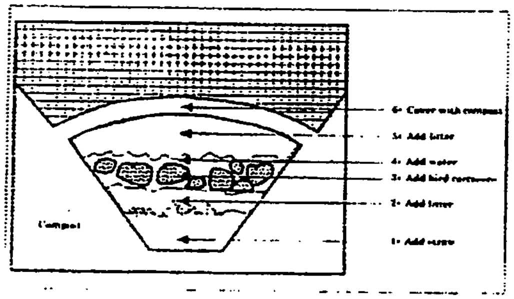

Figure 2.—Loading an in-house composter.

A minicomposter for outdoor use is usually 48" x 48" bin set on a 4-foot square is a workable size. Place the bins on a concrete pad under a roof to protect the compost from excessive moisture, anaerobic conditions, and pests. Outside composters use the same recipe and management as in-house minicomposters, but adjustments can be made to suit individual situations. The time and hand labor required to manage an outside composter must be carefully considered before installation. The cost of an outside minicomposter varies from $500 to $1,500, depending on the materials used.

Composting Compared to Other Disposal Practices

An emerging technology in the early 1990s, composting is now a preferred method of mortality management. It protects the environment and animal and human health, and it does not have quite the risk of air pollution that incineration does. In addition, composting can be scaled up or down in size, with corresponding differences in the grower's costs. Most comparisons between composting and other disposal methods use the price of the two stage composter as the base composter cost. In fact, minicomposters can be built for a third or less of that cost.

Changes in the recipe and design of composters are an indication that this practice is still in development, and further refinements can be expected. Growers interested in using this mortality management approach are urged to contact the appropriate local, state, and federal agencies for assistance. Standard plans and management information for poultry mortality composters are available through the USDA Natural Resources Conservation Service or Cooperative Extension Service offices.

Low interest loans or cost-share funding may be available in some states to help pay for the design and construction of composting facilities. Check with your state agencies and the USDA Consolidated Farm Service Agency to learn more about these programs.

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New Takes on the Rendering Process — Refrigeration, Fermentation, and Acid Preservation

Rendering — the process of separating animal fats, usually by cooking, to produce usable ingredients such as lard, protein, feed products, or nutrients — is one of the best ways to convert poultry carcasses into other products. We are now able to reclaim or recycle almost 100 percent of inedible raw poultry material, including bones and feathers, through rendering techniques.

Until recently, the animal protein in meat and bone meal residues was considered a waste of poultry processing; it was usually discarded, though it could sometimes be used as a fertilizer. Now rendering plants pick up or receive about 91 million pounds of waste annually to supply 85 percent of all fats and oils used in the United States. They also export 35 percent of the fats and oils used worldwide. Rendering operations provide a vital link between the feed industry and the poultry grower; they also help control odor and prevent air and water pollution.

Rendering has not been widely practiced, however, as an on-farm method of poultry mortality management. Few rendering facilities are located in the production area and carcasses do not remain fresh long enough to be delivered long distances. Further, any transportation of the carcasses off-farm could spread avian diseases.

The converse of these difficulties is, however, rendering's great advantage as a management technique, namely, it does remove mortalities from the farm and relieve the grower of environmental concerns related to other methods of disposal. Its potential economic benefit increases as more of the product is successfully recycled. Spurred by such considerations and concern to prevent further nutrient losses, growers and their industry partners are taking a second look at the rendering process.

Efforts to develop appropriate management and handling techniques to overcome obstacles associated with the routine pick up and delivery of carcasses to the rendering plant (especially the possible threat to avian health and the environment) have focused on long and short-term alternatives to the immediate delivery of carcasses for processing. The earliest management adaptations relied heavily on daily pickups and refrigeration; emerging technologies that may be safer and more cost effective include acid preservation, grinding and fermentation, and extrusion.

Preparing for Immediate Delivery

Raw or fresh poultry mortalities that are destined for a rendering plant must be held in a leak-proof, fly-proof container; and they must be delivered to, or be picked up by, a rendering company within 24 hours of death. All mortalities must be held in a form that retards decomposition until they are collected.

Refrigeration

Some producers are experimenting with a technique that combines on-farm freezing or refrigeration and the rendering process to determine whether freezing can be an effective way for growers to preserve the dead birds until they can be rendered. Large custom-built or ordinary commercial freezer boxes are being used to preserve dead birds until they can be picked up and delivered to the rendering plant. Custom-built boxes or units are usually free standing with self-contained refrigeration units designed to provide temperatures between 10 and 20 °F.

Ideally, these freezer units will have no environmental or health impacts. The smaller ones are designed to allow the immediate removal of the carcasses from the grower; the larger ones, to hold the birds frozen until the box is full or otherwise scheduled for delivery to the plant.

Large domestic freezers will hold about 250 to 300 pounds of dead birds. Specifically designed boxes can handle 1,600 to 2,000 pounds of dead birds and are easily loaded through various door arrangements. These units must also be sealed against weather and air leakage. Putting the birds in the freezer in a single layer and on a daily basis helps ensure that all the carcasses will be properly frozen. Fresh unfrozen carcasses are added to the top layer. Temperatures are set to freeze and should be regularly monitored to detect malfunctioning equipment, and overloading is strongly discouraged as that can also inhibit the freezing process.

The freezers remain on farm until the end of each growing cycle when they are emptied into a truck for transportation to the rendering facility. The refrigeration unit never leaves the farm, only the container holding the dead birds is removed or emptied.

Refrigeration is still an expensive option, though most of these units will last roughly 10 years and operate on energy efficient circuit boxes with an operating cost of about $1.50 per day. Transfer of pathogens or harmful microorganisms between farms has not been found to be a problem with this method of collection. Although additional experience is needed to determine the effectiveness of this option, its proponents stress its usefulness as a way to reduce or eliminate potential pollution and improve conditions on the farm.

Fermentation

Fermentation procedures, first proposed in 1984 and not commercially tested until 1992, are a more demanding but safer and perhaps more cost-effective method of preserving carcasses until the industry is prepared to handle their further processing and reuse. In fact, fermentation safely disposes of poultry mortalities by "processing" them on site. The pickled carcasses can be stored until the end of the growing cycle or until sufficient volume is attained for delivery to a rendering plant.

Fermentation begins in a grinder. The carcasses are ground into small particles (each piece measures roughly an inch) and a fermentable carbohydrate is added to the container. The grinding action disperses and mixes anaerobic lactic acid-forming bacteria found naturally in the birds' intestines; the carbohydrate provides the bacteria "opportunity" to ferment the ground mortalities; and the result is the production of volatile fatty acids and a reduction of pH — from 6.3 in the fresh tissue material to the 4.5 pH of the carbohydrate mixture.

It is the decline in pH that effectively preserves the birds' nutrient contents. In sum: the activity of anaerobic bacteria (*Lactobacillus*, sp., which are found naturally in poultry) converts the carbohydrate into lactic acid and lowers the pH to less than 5.0, thus inactivating the pathogenic microorganisms in the carcasses and preserving the organic materials.

The first commercial on-farm fermentation system was designed to accommodate daily broiler mortalities. It consisted of a grinder and tanks housed in a shed equipped with electricity and water. The grinder was constructed to incorporate the carbohydrate during the grinding process. The carbohydrate source may be sugar, whey, corn, or molasses, depending on which of these materials is most available to the grower. In the first commercial facility, corn was added on a 20-percent weight to weight basis.

The mixture of ground corn and mortalities passes from the grinder directly into an enclosed tank where the fermentation process takes place. Sugars in the corn are converted to lactic acid; the pH level drops; and within seven to 10 days, the lactic acid bacteria increase sufficiently to preserve the carcass nutrients. The fermented material can be kept in a stable state for

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several months, easily accommodating its transport at the end of a grow-out cycle.

The equipment should be cleaned routinely. After each use, the grinder can be flushed with a minimal amount of water that can be rinsed into the holding tank. The entire grinder should be disassembled and thoroughly cleaned each month.

The initial investment in this process is relatively high — for the building, grinder and tanks, and their installation. The first commercial system cost $8,200; the value placed on the fermented product was $.02 per pound. The net cost of fermenting the mortalities per pound was estimated at $.045 per pound, or fractionally less than composting ($.048) and almost half the cost of incineration ($.089, using 1992 figures).

Mortalities are a continuous and growing challenge for the poultry industry. The fermentation process is clearly a technology that meets the biological and environmental criteria required for the proper disposal of on-farm mortalities. Growers and their companies must carefully weigh these advantages against the managerial and economic trade-offs involved in selecting this practice.

Acid Preservation

Preserving foodstuff by acidification has been a widespread practice in agriculture. This method of preserving dead birds is the same as the fermentation process except that propionic, phosphoric, or sulfuric acid is added to the poultry carcasses, which are kept in an airtight, plastic container. Sulfuric acid may be preferred because it (1) retards spoilage, (2) excellently preserves the carcass, and (3) is relatively low in cost. However, safe handling and storage of the acids on-farm are important concerns.

Carcasses can be punctured with a blunt metal rod rather than placed through a grinder. Punctured carcasses can be separated from the acid solution without the accumulation of sludge in the holding container.

Selecting a Holding Method

The product resulting from acid preservation and lactic acid fermentation reduces the transportation costs associated with rendering by 90 percent. What is more important, however, is that these processes eliminate the potential for transmitting pathogenic organisms into the rendered products or the environment.

In an expanding poultry industry, the production of manure and mortalities will only increase. Producers should contact the renderers in their area to determine which holding and transportation methods are acceptable, and they must increase their search for safe, cost-effective disposal and reuse methods. Every possible safe method should be explored until each grower determines the method most compatible with his or her situation and management abilities. Rendering, like composting, adds value to the end product that can help offset mortality management costs.

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